Xanthan Gum - The Natural Water for Cosmetic and Personal Care Products

Water-soluble polymers are often found in personal care products to stabilis emulsions and suspensions as well modifying their rheology for sensory or textural effects. Products frequently encountered include synthetic polymers, such as the carbomer series, and the extensive range of cellulose derivatives. These products are often essential for the successful performance of personal care products. However, many other polymers are used and play the same essential role. One such example is xanthan gum, the subject of this paper.

Xanthan gum is an exocellular polysaccharide produced by the bacterium Xanthomonas campestris. It is elaborated at the cell wall surface during the natural life-cycle of the microorganism. The gum encapsulates the cell and is also secreted into or onto the surrounding medium. In nature the bacteria are found on the leaves of Brassica vegetables - the cabbage plant being a favourite host. The gum is produced to aid the survival of the organism. It helps it to adhere to the leaf from which it gains sustenance, it protects it against dehydration, infection and damage from temperature fluctuations and it prevents it from being washed away. It is for many of these reasons that xanthan gum has been exploited as a multifunctional ingredient in food products.

Xanthan gum is a natural CTFA approved additive as well as an accepted food additive (E415,), with the safest classification of ADI (Acceptable Daily Intake) "unspecified".

Production of Xanthan Gum

Xanthan gum is produced commercially in a pure culture aerobic submerged fermentation process. The bacteria are cultured in a well-aerated medium containing glucose, a nitrogen source and various trace elements. To provide seed for the final fermentation stage the process is done in several stages. When the fermentation has finished the broth is pasteurisedto kill the bacteria and the gum is recovered by precipitation with isopropyl alcohol. The final stages involve drying, milling and packaging.

Many quality control measurements are made at all stages of the production process to ensure that a consistent high quality product is always produced.

The production of xanthan gum is a classical example of the application of biotechnology on a large scale coupled with the ability to handle viscous materials.

Fermentation Process Benefits

There are a number of advantages that are directly derived from the use of a fermentation process.

The raw materials used in the production process are all readily available and the controlled nature of the fermentation process ensures that there is no dependence on climatic or other seasonal factors as is the case with seaweed and plantderived gums.

Finally, the fermentation process, with its associated quality control, ensures that a high quality product is always made to the same specification.

Structure of Xanthan Gum

Xanthan gum is a high molecular weight polymer reported to have a molecular weight ranging from 2 to 50 million daltons. The polymer is composed of a five-sugar residue repeat unit. The backbone is composed of polymeric glucose units, thus it is chemically identical to cellulose. The difference between xanthan gum and cellulose, however, lies in the side chains. These units, which occur on average in every second unit in the backbone, are made up of an unbranched trisaccharide unit: a non-terminal mannose, a glucuronic acid and a terminal mannose residue. About half of the terminal mannose residues carry a pyruvic acid residue ketalically linked to the 4- and 6- positions. The non-terminal mannose unit in each side chain contains an acetyl group at position 6.

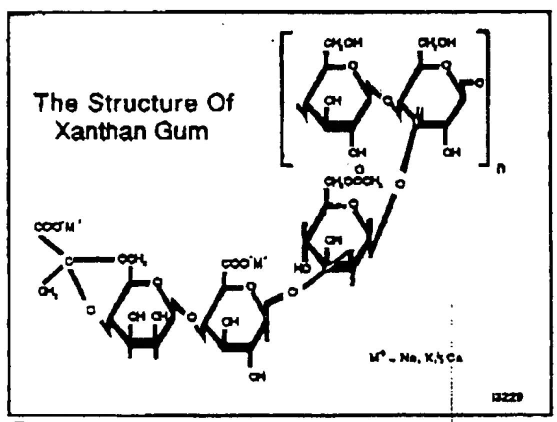

Fig 1

In solution the side chains wrap around the backbone thereby protecting the labile B1-4 linkages from attack. Indeed, it is thought that this protection is responsible for the great stability of the gum under adverse conditions.

Xanthan Gum
View Down Helix Axis

Fig 2

A view of the molecular conformation shows how the side chains completely cover and protect the cellulose backbone. In addition, the unvarying chemical structure provides the gum with its outstanding uniform chemical and physical properties.

PHYSICAL PROPERTIES

The unique molecular structure of xanthan gum is responsible for its interesting and useful properties.

Xanthan gum hydrates rapidly into cold or hot water, to form solutions which have a tendency towards intermolecular chain association resulting in the formation of a complex network of entangled molecules. This state is referred to as the "long range order". When energy in the form of heat or shear is applied to the system these weakly bound aggregates are progressively disrupted resulting in a less ordered structure referred to as a "local order". As the amount of energy is increased even further all intermolecular association is lost. At this stage the solution is composed of random segments. These changes have been monitored by optical rotation which indicates that a conformational change is taking place. In practise these changes are seen as a decrease in solution viscosity.

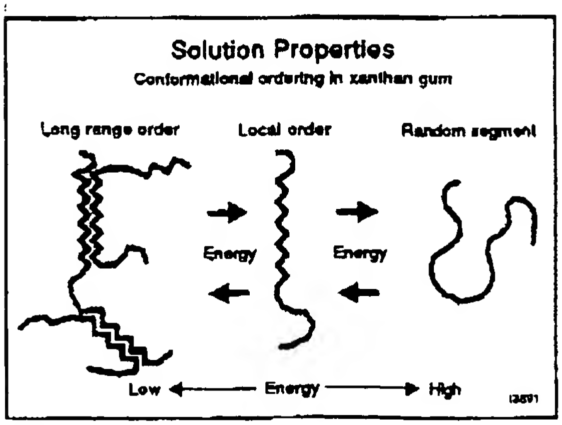

Fig 3

When the applied energy is reduced or removed, or as the solution is cooled, the network structure is regenerated. This is manifest by an increase in solution viscosity.

Rheology

Xanthan gum solutions are viscous even when the gum is used a low level. At low use levels the viscosity increases linearly with increasing concentration; at higher concentrations the viscosity curve plateaus out indicating a strong competition for water.

Xanthan gum solutions exhibit pseudoplastic flow properties. This is characterised by a decrease in apparent viscosity in response to an increase in shear rate. In contrast, Newtonian fluids show a constant viscosity which is independent of the shear rate. A good example of a Newtonian fluid is water which shows no tendency to thin down during mixing operations.

The pseudoplastic or shear-thinning behaviour of xanthan gum solutions is obvious when compared to solutions of other natural water soluble polymers such as guar gum and sodium alginate (Fig 4). As the shear rate is increased the apparent viscosity of the xanthan gum solution is seen to drop. In practise this means that solutions of xanthan gum are easier to pump, spray, mix and homogenise than solutions of the other gums.

At low rates of shear xanthan gum solutions exhibit very high viscosities compared to other gums at typical in-use concentrations.

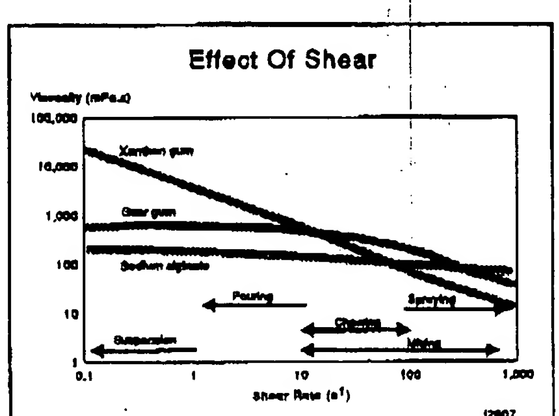

Fig 4

Figure 5 illustrates the relationship between viscosity and shear rate for xanthan gum over a shear-rate range between 0.01 and 10,000 reciprocal seconds.

Due to the uniform relationship between shear rate and apparent viscosity the suspending ability of xanthan gum is predictable and uniform over a wide range of conditions and concentrations.

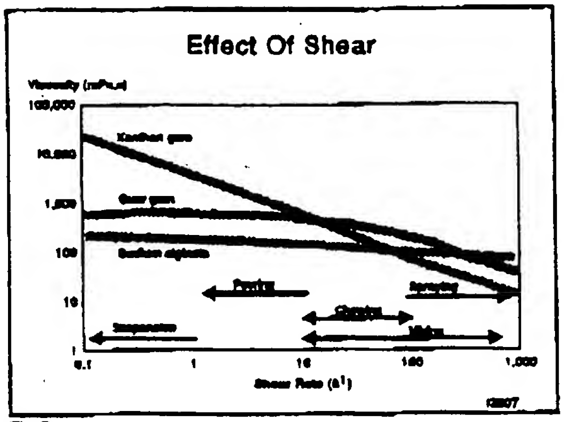

Fig 5

In addition there tends to be little hysteresis. The recovery of viscosity when shear is removed is almost instantaneous.

This lack of hysteresis (also referred to a thixotropy) is particulary important in maintaining stability of emulsions and suspensions after mixing.

Solutions of xanthan gum appear almost gel like at rest. This is owing to the viscoelastic rheology resulting from long range conformational ordering.

The elastic limit of xanthan gum solutions is sufficient to stabilise suspensions and emulsions, but is lower than that of synthetic products and as such has a less obvious gel character.

Emulsions and Suspensions

The pseudoplasticity and viscoelasticity of xanthan gum in solution make it an excellent stabiliser of cosmetic lotions and creams consisting of oil-in-water emulsions. Stability of the emulsion is achieved by the high apparent viscosity or gel like nature of the aqueous phase preventing coalescence and separation of the dispersed oil phase. Even under modest agitation, for example that encountered when a formulated product is transported, stability is maintained owing to the high elastic modulus of xanthan gum solutions. It must be stressed, that while coalescence is prevented, xanthan gum does not have surface active properties so an emulsifier is needed. However, the prevention of droplet-droplet collisions caused by the high apparent viscosity reduces the level of emulsifier needed. An attractive feature of xanthan gum is that, while stability is maintained, emulsions still have acceptable flow and handle characteristics owing to the lowered viscosity when shear is applied.

The stabilisation of suspensions with xanthan gum is achieved in the same way as emulsions. In this case, the discontinuous phase is a solid material with a tendency to settle.

COMPATIBILITY AND STABILITY

Salt Stability

Xanthan gum solutions are compatible and stable in the presence of many salts. In a number of cases, compatibility is limited only by the solubility of the salt itself.

Whilst xanthan gum is compatible with high levels of salts, it is always advisable to hydrate the gum directly into water before addition of the salt (Fig 6).

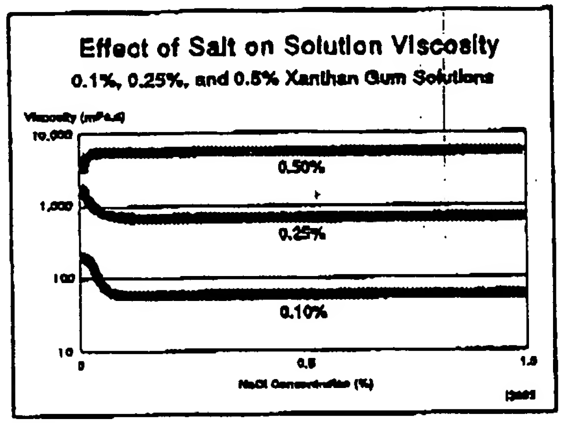

Fig 6

An interesting effect is seen with deionised water however, when a monovalent salt such as sodium chloride is added. At or below 0.25% xanthan gum concentration the salt causes an initial decrease in viscosity. At higher concentrations, viscosity increases with added salt. At a monovalent salt level of 0.1%, the viscosity plateau is reached for all gum concentrations, and further addition of salt has no effect on viscosity. These effects are due to ionic interaction between the anionic xanthan gum polymer and cations such as sodium ions. Thus a minimal level of electrolyte is necessary to stabilise the viscosity of xanthan gum solutions.

Typical process waters often contain at least 0.1% electrolyte and so no problems are anticipated with variable viscosity, although care must be exercised with deionised water. This salt stability is useful as it ensures uniformity in production runs where subtle variations in electrolyte level may impact on other thickeners.

Effect of Temperature on Viscosity

Figure 7 shows the viscosity of xanthan gum solutions containing a small amount of electrolyte is only moderately affected by temperatures in the range from 0 to about 60_C. Thus the stabilising influence contributed by xanthan gum will remain unchanged over a broad range of thermal conditions. Above the transition temperature of approximately 50-60_C, the viscosity drops sharply. The presence of

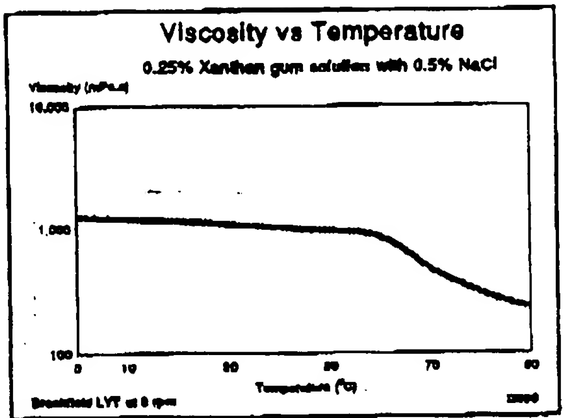

Fig 7

salt improves the thermal stability and ensures that the majority of the viscosity returns when the solution is cooled even after heating to retort temperatures.

The loss of viscosity when the transition temperature is exceeded explains the importance of xanthan gum in thermally processed products, where the low viscosity achieved at high temperature improves heat transfer, and can, in some situations result in reduced process times.

Effect of pH on Viscosity

Xanthan gum is extremely stable over a wide pH range (Fig 8). From pH2 to 12 there is little change in viscosity. Outside these values there is some viscosity decrease. The stability is utilised in many food systems, and may offer processing benefits in personal care products.

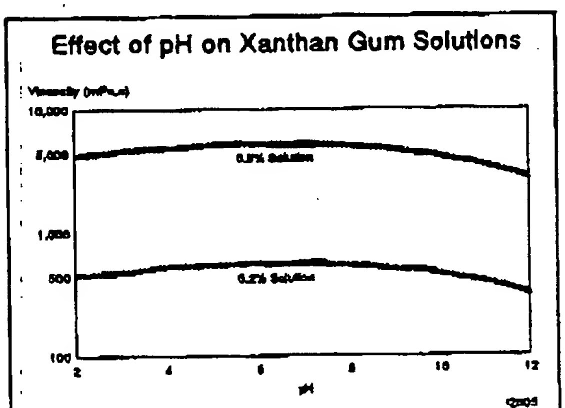

Fig 8

Alcohol

While xanthan gum will not dissolve directly into alcohol, solutions of xanthan gum are compatible with alcohol. Products containing alcohol may be formulated, to contain up to 60% watermiscible solvents such as ethanol.

Thickeners

Xanthan gum is compatible with most water soluble polymers and mineral thickeners, both synthetic and natural, and can offer some beneficial textural changes.

Reactions

While having excellent chemical compatibility and stability, being a natural product, xanthan gum does exhibit some reactions that need to be taken account of (Fig 9).

Xanthan gum reactions

Trivalent metal ions

Oxidizing agents

Cationic surfactants

Fig 9

Summary

Xanthan gum is a natural, high viscosity, water soluble polymer. It hydrates directly into hot or cold water to form viscous solutions with pseudoplastic rheology. These properties enable it to act as a stabiliser of many suspensions and emulsions with easy handling during processing and application.

The temperature stability of xanthan gum ensures uniform performance in all conditions and lends itself to any processing equipment.

The superior chemical compatibility and stability enable it to function effectively in a wide range of products and tolerate formulation changes.

Typical Applications

Examples of the range of application which benefit from the physical and chemical properties of xanthan gum are detailed below.

Application

Creams

Lotions

Shampoos

Gels

Toothpaste

Suspension

Fig 10